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EASTERN FOREST TREE DISEASES IN RELATION TO STAND IMPROVEMENT

By GEORGE H. HEPTING

Field Assistant, Division of Forest Pathology, Bureau of Plant Industry
United States Department of Agriculture

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By GEORGE H. HEPTING,[1] *Field Assistant, Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

Stand-improvement operations are designed to bring about better conditions of forest growth. They aim to put the stand into such condition that the desirable trees will make faster growth and the stand as a whole will produce material of better quality. Trees to be favored in such operations may be selected both on the basis of species and on that of individual quality. This selection is a matter of major importance; a mistake in selection early in the life of the stand is very likely to have an adverse effect on the future development of the forest. It is important that the trees selected to be favored be free from disease and that they be protected from serious infection. Consequently, in any stand-improvement operation careful attention should be given to the diseases present in the stand.

This publication presents some essential facts regarding tree diseases that should be available to those performing stand-improvement work in the forests of the Eastern States.[2] It treats of a number of the more common and important forest-tree diseases of the East, indicating their principal distinguishing characteristics and measures for their control. It treats also of certain general pathological considerations that are involved in all stand-improvement operations. It describes certain threatening introduced diseases on which reports of observations are desired.

Anyone encountering tree diseases that he cannot identify on the basis of information given in this manual can obtain further information by writing to the Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture, Washington, D.C. In such cases inquiries should preferably be accompanied by specimens.

FOREST PATHOLOGY IN STAND IMPROVEMENT

Forest trees are subject to disease at all ages, from the seed stage through maturity. No part of the tree, whether roots, wood, bark, leaves, flowers, or fruit, is free from the hazard of disease. Most tree diseases are caused by fungi; many, however, are caused by bacteria, by leafy plants such as the mistletoes, by nonparasitic agencies such as frost, heat, or poisonous gases, and by filterable viruses.

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[1] This manual is a compilation of information from various sources. Special acknowledgment is due to Perley Spaulding, J. S. Boyce, D. S. Welch, J. F. Martin, and C. S. Moses.

[2] For a discussion of stand-improvement measures applying specifically to the southern Appalachian forests and more or less generally to forests throughout the East, see Measures for Stand Improvement in Southern Appalachian Forests, Emergency Conservation Work Forestry Publication No. 1. 57 p., illus. 1933.

Tree diseases operate in various ways to reduce the final yield of any stand of timber and the quality of the material produced. Root diseases, such as that caused by *Armillaria mellea*, by rotting and killing roots, reduce a tree's capacity for absorbing water and mineral nutrients from the soil, and may cause the tree's death. Bark diseases, such as that caused by *Strumella coryneoidea*, produce open wounds on the bole many of which never heal, thus permitting decay and often causing the stem to break. Wood-rotting diseases, such as that caused by *Fomes igniarius*, reduce or destroy the merchantability of timber. Leaf and needle diseases, such as those caused by the leaf-cast fungi on pines, reduce the photosynthetic area of the trees and sometimes defoliate them. The cone rusts of conifers may greatly reduce seed crops.

Most of our forest tree diseases are native, that is, so far as we know have always existed in this country. This group includes many of our heart rots. Native diseases rarely become epidemic; the organisms causing them are more or less in biological balance with their hosts. Sometimes this balance is disturbed by unusual weather conditions or other factors, and a native disease temporarily becomes epidemic. When the disturbance of the biological balance comes to an end the disease resumes its former status, in which through slow, constant action it effects cumulative damage. Many of our most destructive diseases, for example white pine blister rust and chestnut blight, are not native but are known to have been introduced into this country from foreign lands. Parasites brought into a new region often find some tree species there particularly susceptible to their attack, partly because of the lack of any established balance between parasite and host. This results in an epidemic.

A tree chosen in a stand-improvement operation to be left as a crop tree should be free from any disease that will cause it to be of poor quality, to make poor growth, or to be prematurely eliminated from the stand. Evidences of the presence of such diseases are cankers, fungus sporophores, and exposed decayed wood. The health of the individual is of equal importance with its species and form. Preferably, the crop tree should be of one of the species less susceptible to disease.

Stand sanitation involves removing from the stand such trees as have cankers or fruiting bodies of fungus parasites or are for any other reason a source of infection to the crop trees. While the trees chosen to compose the final stand must themselves be free from disease, the extent to which stand sanitation should be applied varies according to the diseases concerned, the availability of markets for wood removed, and the intensiveness of the silvicultural treatment.

The removal of diseased trees in stand sanitation not only reduces the sources of infection but also gives young thrifty timber an opportunity to occupy space formerly occupied by worthless trees.

HEART-ROT DISEASES

Practically all wood decay is caused by fungi. The heart-rot fungi are those the activity of which is confined, for the most part, to the heartwood and old sapwood of living trees.

TYPICAL LIFE HISTORY OF A HEART-ROT FUNGUS

The heart-rot fungi are similar in life history. When the decay caused by a heart-rotting fungus has progressed for a number of years the fungus often produces a fruiting structure, known as a sporophore, conk, or punk (figs. 2–9). The conks usually protrude from branch stubs, from fire scars, or from other points where the wood of the decayed tree is exposed. From each conk are produced annually millions of tiny spores. In conks of the genera Fomes and Polyporus, the spores are produced in tubes which form the lower portion of the conk and open at its lower surface. In conks of certain other genera of wood-destroying fungi the spores are produced on gills or teeth or in labyrinthine cells. When released from the conk, the spores are carried about by air currents. When one of them comes to rest upon the exposed wood of a tree of a susceptible species and conditions are suitable it germinates there, sending a fungous filament into the wood. From this filament the fungus develops, spreading up and down from the point of entrance, rotting the wood as it goes. True heart-rotting fungi gain entrance most readily through exposed heartwood. Their most common paths of entrance are dead branch stubs and fire scars.

Heart-rot fungi working up from fire scars in some cases cause ultimately only a few feet of butt rot; in others they penetrate throughout the bole of the tree. The difference depends partly upon the species of the fungus. Decay in young oaks on sampled areas in the bottom lands of the lower Mississippi Valley was found to have progressed upward from open fire scars at an average rate of about 2.3 inches per year. While the rate is probably slower farther north, and varies with the tree species, this serves to indicate the importance of fire scars in young timber. The size of fire scars has little relation to the hazard of decay, aside from the fact that very small scars may heal over before decay can become established.

TREATMENT OF CONKY AND FIRE-SCARRED TREES

In stand-improvement operations no tree with a conk should be selected as a crop tree. Even if a conky tree is in fairly good condition when the stand is worked, in most cases it will be worthless by the time the stand reaches merchantable size. If stand sanitation is being practiced all conky trees should be felled or girdled, unless they are needed as seed trees and can be expected to remain merchantable until the time of utilization. All conks on felled trees or within reach on girdled trees should be knocked off. Whenever practicable, conky trees should be removed from the forest or burned, since some heart-rot fungi continue to fruit after the tree dies.

Any trees with open fire scars are to be discriminated against in stand-improvement operations. Trees released to compose the final stand should whenever possible be trees free from fire scars. Very few fire-scarred trees escape infection by wood-destroying fungi. Fire-scarred timber, in addition to being ultimately of no value or of reduced value, occupies space that might be used to grow thrifty timber. It is therefore suggested that in young stands where there is a scattering of badly fire-scarred old-growth trees of low commercial and silvicultural value these trees be girdled or felled.

DECAY FACTORS IN SPROUT THINNING

One of the most important phases of improvement cutting in the sprout hardwood region of the East is the thinning of sprout clumps. In the northern hardwoods such clumps are not common. In the oak region, however, they are very common, particularly in the oaks, yellow poplar, basswood, and red maple. It often appears desirable to remove certain sprouts from a clump so that the remaining one or two stems will make faster diameter growth. In the case of two or more sprouts more than about 3 inches in diameter breast high that are joined at the base, the removal of one sprout creates a decay hazard in the sprout or sprouts remaining. Decay fungi entering through the stubs left when companion sprouts are removed, or through the wounds caused by sprout removal, often cause serious butt rot in the remaining stems, and sometimes work far up into the

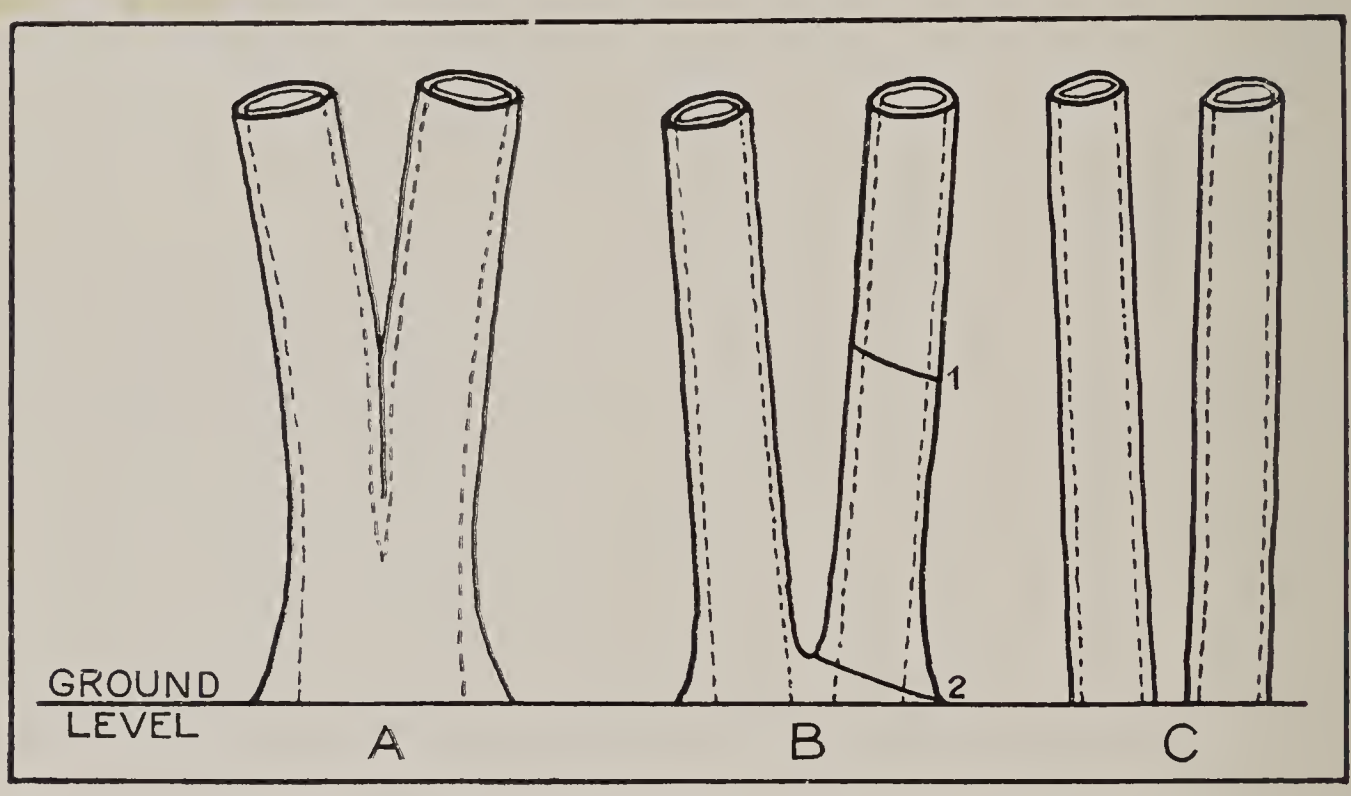

FIGURE 1.—Three common types of twin hardwood sprouts: A, High-union type, with stems fused a foot or more above the ground; B, low-union type, with stems fused close to the ground; C, separated type, with stems separate to the ground. Extent of heartwood is shown by dotted lines. High and low cuts are shown in B by 1 and 2, respectively.

boles of these stems (fig. 8). Where it is highly desirable to remove companion sprouts certain precautions should be observed to reduce the chances of serious decay in the remaining stems.

Figure 1 illustrates the three common types of sprout twins. The high-union type (A), fused a foot or more above the ground, is common in the oaks; the low-union type (B), fused close to the ground, is found in various species; and the separated type (C) is common in red maple. Individuals more than 3 inches in diameter in a pair of the high-union type should be treated alike; either both stems should be removed or both should be left. As is shown in figure 1, the heartwood cylinders of two stems with a high union connect well above the ground line. This connection affords a bridge by which decay fungi entering the cut surface of a removed stem can enter the remaining stem (fig. 8). In the two other types of sprout twins, as is shown in figure 1, the heartwood cylinders are

separated to the ground by a zone of sapwood. Pairs of young trees of these two types can be thinned with less danger of decay than can the high-union type. In thinning any sprout twins in which the stems are 3 inches or less in diameter, it is best to make a low cut such as that shown in figure 1, B2. This may enable the wound to heal before serious decay sets in. If the stems are more than 3 inches in diameter one may be cut at any convenient height, such as that shown in figure 1, B1, or girdled. Although the wound may heal somewhat more slowly if a high stub is left or the sprout is girdled than if a low flush cut is made, the decay hazard is believed to be little or no greater and much labor can be saved. The low, slanting, flush cut requires careful use of the ax and requires more time than a high cut or girdle. The bark around the edge of such a cut must not be knocked loose, as this will delay healing.

It is to be borne in mind that in any thinning of sprout twins the butt-rot hazard is high; the measures just described tend only to reduce, not to remove, the chances of decay. In sprout stands that are fire scarred a high decay hazard already exists, so that thinning may be conducted in any way desired without appreciably increasing the chances of decay.

Sprouts arising from old stumps show great resistance to decay from the parent stump (except in scarlet oak and possibly a few other species).

IMPORTANT HEART-ROT FUNGI

The more important species of heart-rotting fungi in the Eastern States will be discussed individually.

FOMES IGNIARIUS

Fomes igniarius causes a heart-rot disease in practically all hardwoods throughout the United States. It is highly destructive on aspen in the Lake States and the Northeast and is common on the northern hardwoods, particularly beech. Its range of importance in the East extends from Canada south into Virginia. In the southern Appalachians it is considerably less prevalent.

The conk of *F. igniarius* (fig. 2) is more or less hoof-shaped. Its lower surface is brown. The upper surface is black and hard, and is usually much checked. Usually conks are not produced until decay has made considerable progress in the tree. In the northern hardwoods decay extends, on the average, about 7 feet or farther in either direction from a conk of this fungus.

FOMES RIMOSUS

Fomes rimosus causes a disease in locust only. It occurs wherever locust grows, being particularly abundant and severe in the southern Appalachians. This is the most common and the most important heart-rot fungus attacking locust. Any wounded black locust, whether young or old, is subject to its attack. The fungus is able to gain entrance through dead sapwood as well as heartwood. The decayed wood has a characteristic yellow color.

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The conk (fig. 3) is hard, woody, and shelving. Its lower surface is brown; its upper surface is very rough, dark brown to black, and checked. The presence of conks indicates considerable decay. Conks may be found emerging from dead branch stubs, dead areas on the trunk or branches, old locust-borer injuries, or exposed roots.

FOMES NIGRICANS

Fomes nigricans causes a disease chiefly of the birches, particularly paper and yellow birch, and is of considerable importance

FIGURE 2.—*Fomes igniarius* on aspen.

throughout the northern hardwood region and the Lake States. In the appearance of the rot, the activity of the decay, and the method of attack this fungus is identical with *F. igniarius*.

The conks (fig. 4) are usually sterile, dark brown to black, clinker-like masses occurring on open wounds with protruding swollen edges. Evidences of the presence of this disease in addition to the conks are deep pits in the trunk, with swollen margins. These pits are conical depressions usually several inches wide at the surface of the trunk, and are very conspicuous on the birches. The presence of conks or of these pits indicates that the tree is practically worthless.

FOMES APPLANATUS

Fomes applanatus, which causes primarily a decay of dead material, causes an important disease in living trees of certain species, particularly beech and sugar maple. It is extremely common throughout the East. The disease is not nearly so severe as that caused by *F. igniarius* except on beech in northern New England and occasionally on eastern cottonwood. It can cause limited decay in any hardwood, and is commonly found causing butt rot behind fire scars. The conks are large and of the shelving type (fig. 5). They are of a woody consistency, with a grayish upper surface and a white lower surface that darkens when scratched.

FOMES FOMENTARIUS

Fomes fomentarius, like *F. applanatus*, causes decay primarily of dead hardwood material. It occurs throughout the East, but is especially common in the northern hardwood region. The fungus

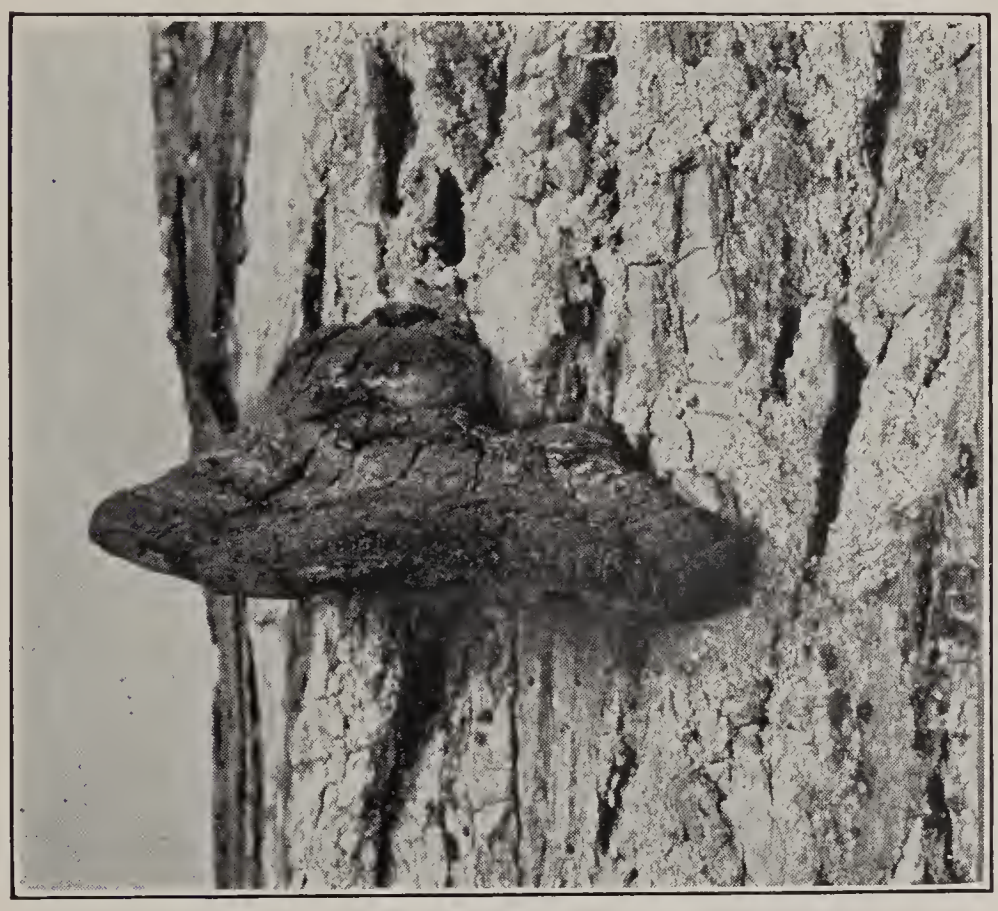

FIGURE 3.—*Fomes rimosus* on black locust.

works in down wood and on snags and dead branches, particularly of yellow birch. While mainly a saprophyte, it is capable of causing local decay in living birches, especially yellow birch. It enters through any exposed dead wood, either sapwood or heartwood, or through decayed branches. Its sphere of activity is chiefly limited to the vicinity of a wound. The conks (fig. 6) are distinctly hoof-shaped. They are gray and smooth on the upper surface and light tan on the under surface. The pores are large as compared with those of *F. igniarius* and *F. applanatus*.

FOMES FRAXINOPHILUS

Fomes fraxinophilus causes a disease of white ash and occurs throughout the range of that species. The disease is particularly prevalent in the western part of the range of white ash (Iowa, Missouri, and Kansas) and in the Mississippi Valley. In the devel-

opment of the decay and in the method of attack *F. fraxinophilus* is similar to *F. igniarius*. The conks are hard and woody, and in shape resemble those of *F. rimosus* (fig. 3). On the upper surface they are grayish-black or black and very rough; on the lower surface, white to straw colored, with large pores.

F. fraxinophilus is likely to produce conks after but little decay; the extent of decay cannot be determined from the presence of conks of this fungus, as can be done with a fair degree of accuracy in the case of *F. igniarius* and *F. nigricans*. It is a typical heart-rotting wound parasite, capable of rotting the entire heartwood of a living tree.

FIGURE 4.—*Fomes nigricans* on paper birch.

FOMES CONNATUS

Fomes connatus causes a disease primarily of the maples, particularly red and sugar maple, and occurs occasionally on other hardwoods. It is found throughout the East, being most common in the northern hardwood region. The conks are small, white, and corky in texture. Often, several of them occur together. Almost invariably the conks have moss growing on their upper surfaces. The fungus may enter the tree through any kind of wound, but usually fruits on a seam or scar near the base of the tree. As a rule the decay extends but a short distance from the conk. Examination of a large number of red maples in New Hampshire with conks of this fungus showed that the decay extended only 1 to 3 feet in either direction from the conks.

POLYPORUS SULPHUREUS

Polyporus sulphureus causes a disease in many hardwoods and conifers, and occurs throughout the United States. It affects principally the oaks, and also black walnut, butternut, and the maples. It is particularly abundant and causes especially severe injury on oaks in the southern Appalachians. One of the most common avenues of entrance of the fungus is fire scars, on which it is commonly found fruiting. The fungus enters also through branch stubs and other open wounds. It is capable of living and producing conks many years after the host tree has been cut, and fruits abundantly

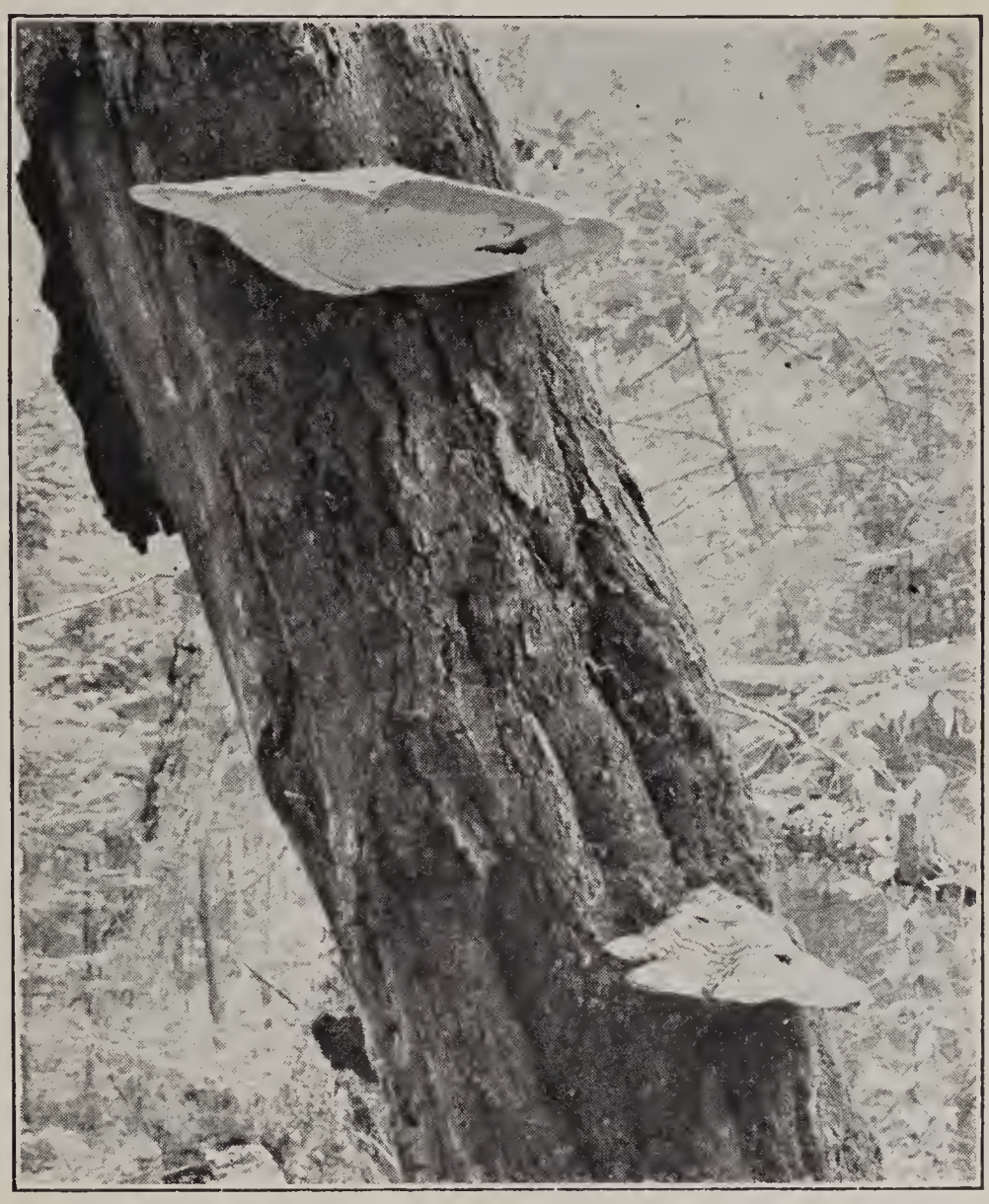

FIGURE 5.—*Fomes applanatus* on beech.

on the decayed stumps of affected trees. The rotted wood is brown and crumbly, and resembles charcoal.

The conks when fresh (fig. 7) are soft, fleshy, and sulphur yellow or orange colored. Usually they form a series of shelves or plates, and are rather irregular in shape. When old and weathered they are a dirty gray. They are formed new each year. The presence of conks of this fungus, as a rule, indicates several feet of decay beyond the conks.

DAEDALEA QUERCINA

Daedalea quercina causes a decay in oaks and chestnut. Its important range in the East extends from central Virginia west and north throughout the oak range. Primarily it is a saprophytic fungus that causes serious losses through decay in structural tim-

bers, ties, poles, etc., and that also causes decay of fallen trees in the woods and fruits abundantly on oak and chestnut stumps. If given a suitable avenue of entrance into living trees, it is capable of causing considerable butt rot. When pairs of oak sprouts are thinned this fungus often enters stubs and works down through them into the remaining sprouts, or enters the remaining sprouts through wounds at their bases (fig. 8B). It causes a pale-brown

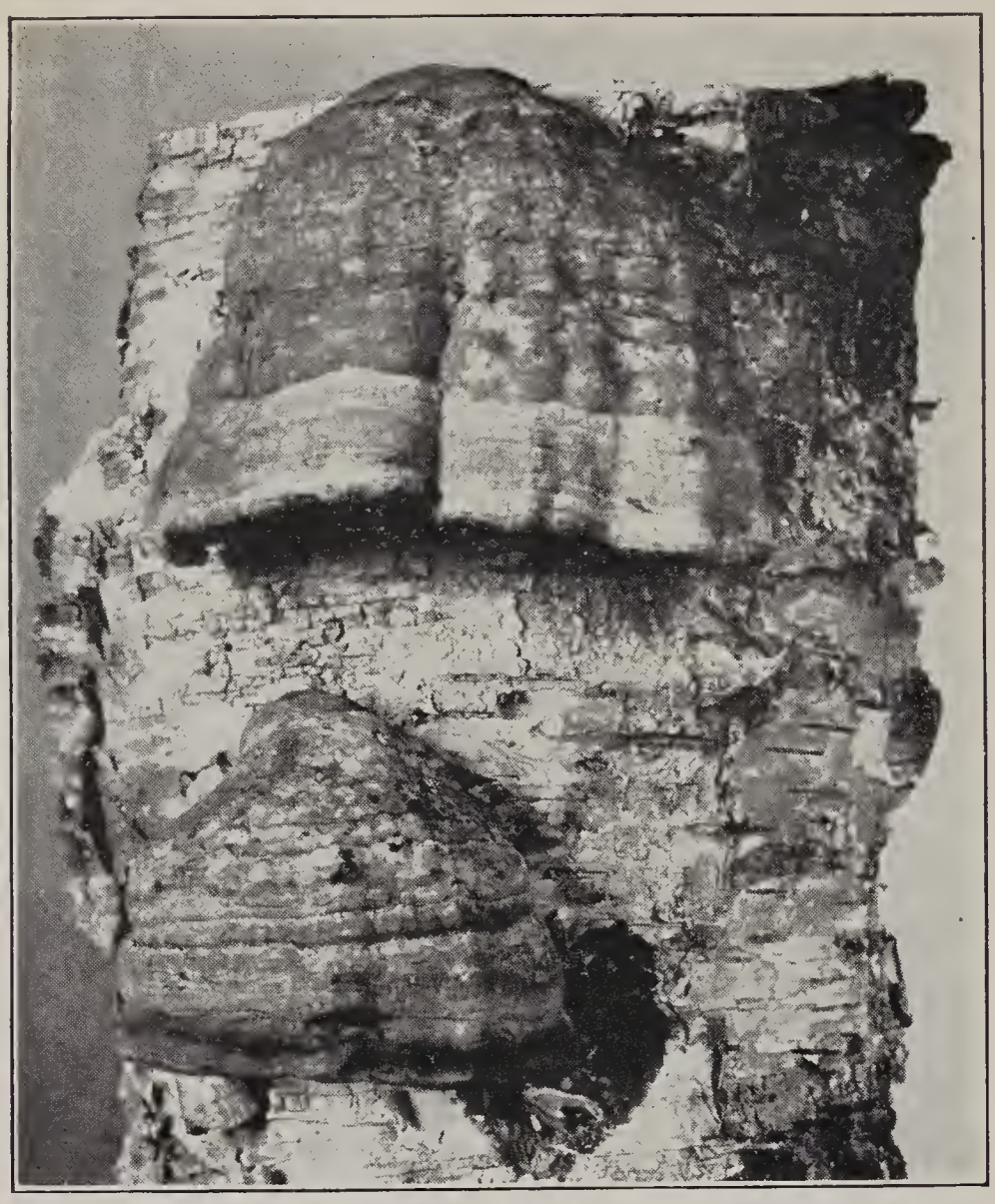

FIGURE 6.—*Fomes fomentarius* on yellow birch.

crumbly rot, with white felts of mycelium often present in the decayed wood. The conk is leathery to corky in texture, grayish on the upper surface and straw-colored on the lower surface. The pores in the lower portion are very large and are in the form of labyrinthiform chambers. In shape the conk varies from flat and shelflike to wedge-shaped (fig. 8A).

HYDNUM ERINACEUS

Hydnum erinaceus causes a disease occurring in many hardwood species, chiefly the oaks. It has been found abundantly on both the southern red oak and the white oak. Its large white fruiting bodies are very conspicuous. It occurs throughout the East, extending into the Mississippi Valley. In the Northeast a similar disease caused by *Hydnum septentrionale* largely replaces that caused by *H. erinaceus* on the oaks and beech, although the latter also is present. *H. erinaceus* enters through dead branch stubs, tunnels of the oak borer, and other wounds exposing heartwood. The decayed wood is

very soft and mushy, with a high water content, and usually contains felts of mycelium. Trees decayed by either of the Hydnums mentioned are very likely to be hollow, as the decayed wood often completely decomposes.

The conks of these Hydnums are large, soft, fleshy, white masses, with long teeth hanging from their lower surfaces (fig. 9). Whereas in Fomes and Polyporus the spores are formed within tubes, in the Hydnums they are formed on the surfaces of the teeth or spines. The presence of the fruiting bodies of *H. erinaceus* or *H. septentrionale* is evidence of considerable decay.

FIGURE 7.—*Polyporus sulphureus* fruiting at the base of a tree.

TRAMETES PINI (KNOWN ALSO AS FOMES PINI)

Trametes pini causes the most important disease of conifers in the United States. It attacks most of the coniferous species in the East, and is especially important on northern white pine and spruce in the Northeast and the Lake States and on the southern pines. The fungus gains entrance, in the great majority of cases, through dead branch stubs containing heartwood. Larger and older trees are much more likely to be infected with it. The decay progresses through the stubs into the heart of the tree. When the fungus has been working in a tree for some years the conks appear, often in large numbers on the under side of dead branches but sometimes singly on the trunk. The latter condition is common in the South. Other common diagnostic characters are exudation of resin at the branch scars and punky knots disclosed upon cutting into branch scars.

The conks are brownish black and rough on the upper surface, sepia brown on the lower surface. They vary widely in shape; some lie flat on a branch, some protrude in the form of a shelf. They are easily recognized by their color and irregular shape. In many cases the pores on the under surface are not perfectly round but somewhat irregular in outline.

FIGURE 8.—*A*, *Daedalea quercina* fruiting on dead stub at base of red oak. *B*, section of tree shown in *A*, showing decay extending from rotten stub into main stem through connecting heartwood.

BARK DISEASES (CANKERS)

Certain fungi and bacteria work in the bark of living trees, killing the bark and producing what are known as bark lesions or cankers. On trees thus affected healing folds often form around the edges of the cankers, tending to heal over the injury. Sometimes, as in the case of the chestnut-blight canker, the fungus causing the canker works so fast that the lesion never gets a chance to heal, and the tree is rapidly girdled. In the type of canker disease (e.g., the Nectria canker) in which inactivity of the fungus during the active period of the tree permits healing to begin, the fungus during its next active period usually kills back the healing folds and extends the lesion still further. A continuation of this process year after year produces the "target" type of canker characteristic of some fungi (fig. 10). As a result of this process, often the tree is finally

FIGURE 9.—Fruiting body of *Hydnum erinaceus*.

girdled, is broken over at the point weakened by the canker (fig. 13), or is decayed by wood-destroying fungi that have entered through the wood exposed by the canker.

Cankers are especially prevalent in young trees of the size usually encountered in stand-improvement operations, and it is in timber of this size that the work of canker prevention and removal should begin. It is necessary to have some knowledge of canker diseases to be able to recognize cankers as differing from mechanical injuries. While a mechanical injury is continually healing, a canker is continually spreading, so that the ability to distinguish between the two is vitally important in choosing trees to be left as crop trees.

Control measures for the different canker diseases will be discussed under the individual diseases.

NECTRIA CANKER OF HARDWOODS

Nectria canker of hardwoods is caused by a species of Nectria the specific name of which is unsettled. A great variety of hardwoods are affected by it. Those most frequently affected include red maple, basswood, sweet and yellow birch, yellow poplar, black walnut, and

the oaks. The disease is widespread over the East. It more or less follows the range of the northern hardwoods (beech, birch, and maple), and is common on yellow poplar and black walnut in the southern Appalachians. The tree species most seriously affected vary according to localities.

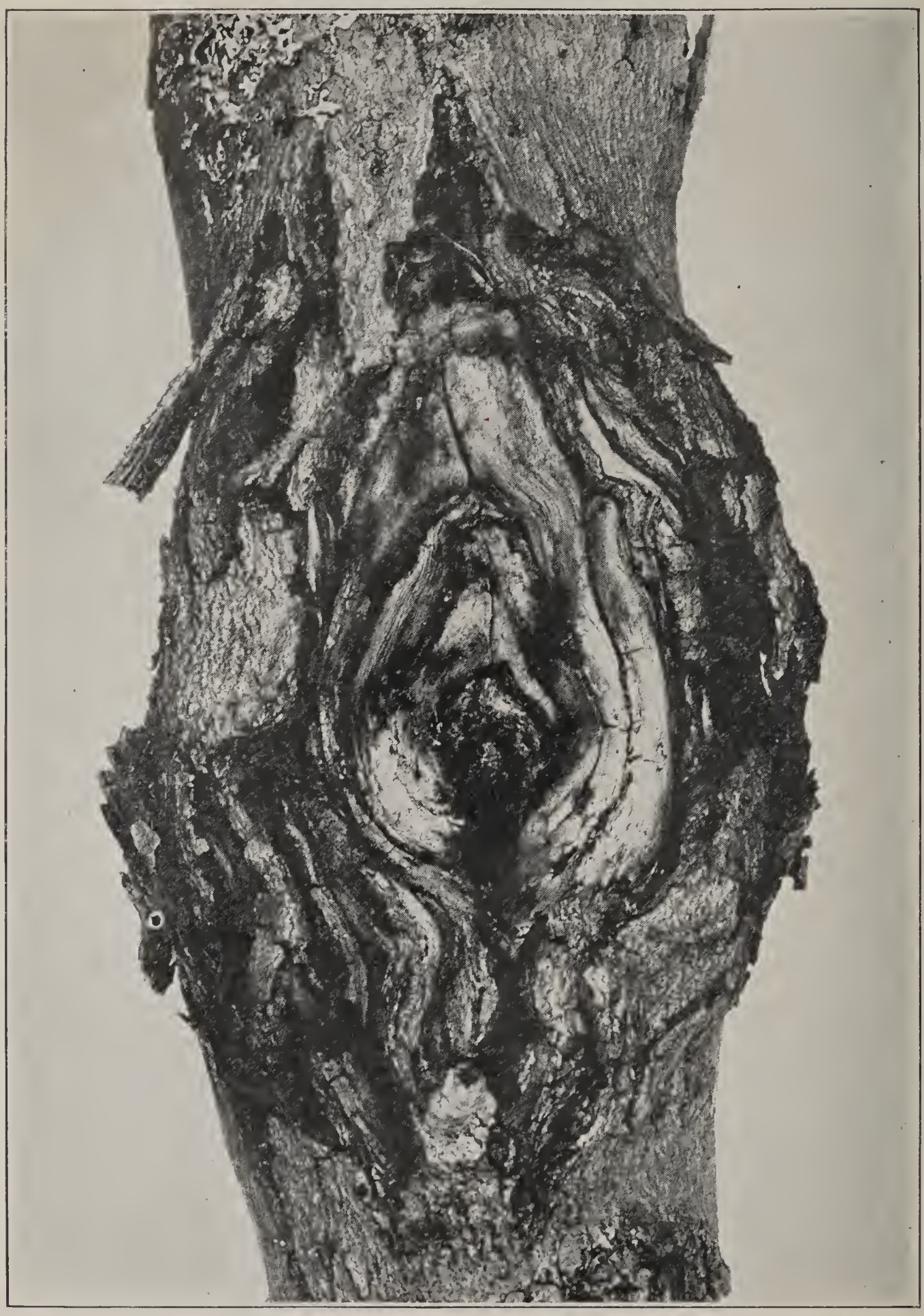

FIGURE 10.—Nectria canker on red maple, showing characteristic target form.

The disease is readily recognized by the characteristic "target" cankers, or "cat faces" (fig. 10), resulting from the killing back of successive healing folds. These killed folds are conspicuous be-

cause the bark falls off them soon after they die. Except in basswood and possibly yellow poplar, which it may enter through any bark injury, this fungus usually enters through a small dead branch stub. From this point it spreads into the bark, forming the canker. Often the stub through which the fungus entered can be found in the center of the canker. Spores of the Nectria fungus are produced in abundance around the edges of the cankers in tiny red balloonlike structures, especially in the spring and fall.

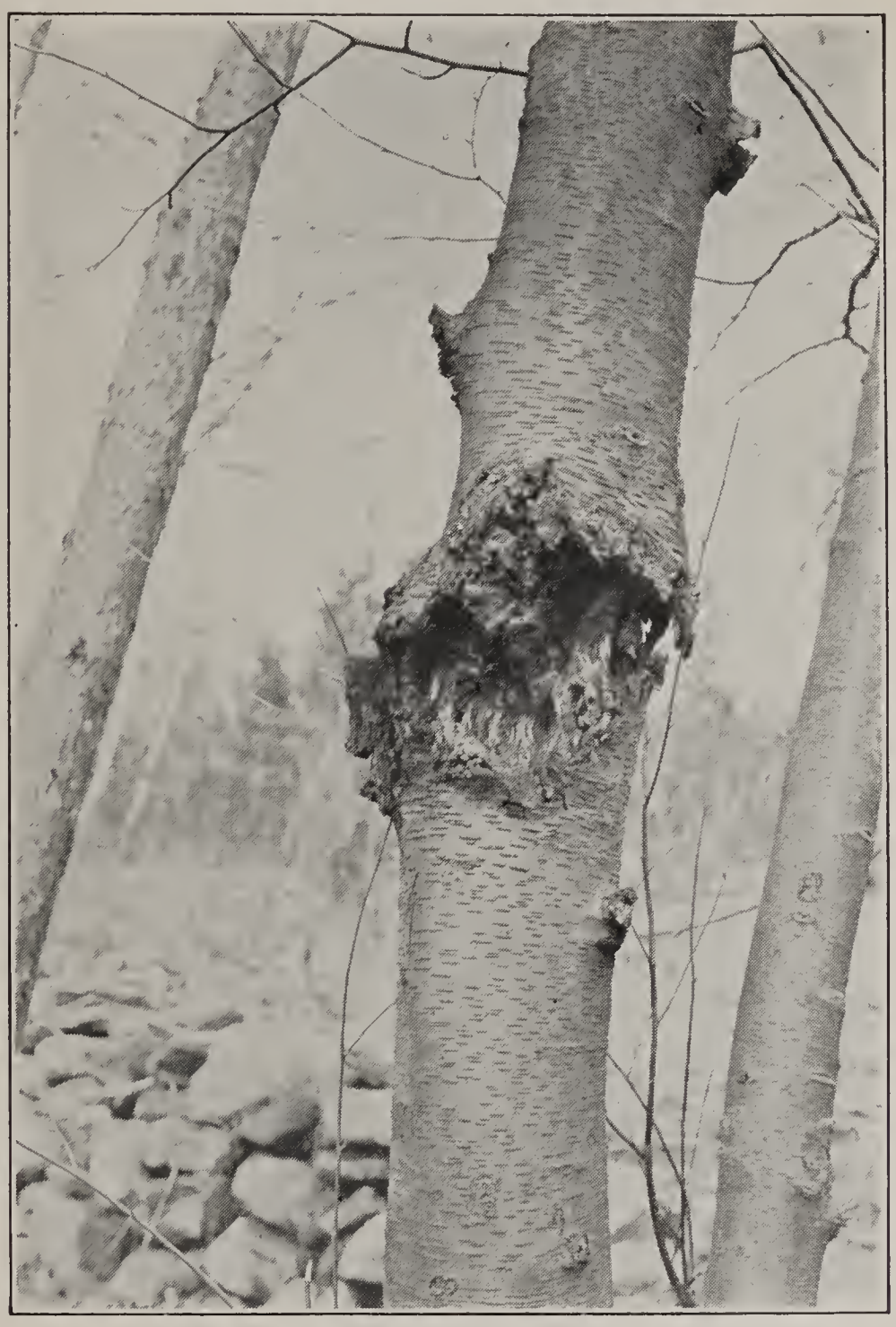

FIGURE 11.—Nectria canker on sweet birch.

Trees bearing Nectria cankers in many cases never survive to produce timber, but weaken at the cankers (fig. 11) and subsequently break over. Trees that do survive are likely to be decayed or at least to produce defective timber.

No trees bearing Nectria cankers should be selected as crop trees. If stand sanitation is being practiced all trees, no matter of what species, bearing Nectria cankers should be eliminated. If felled they should be removed from the forest or burned; they must not be allowed to lie on the ground, because the Nectria fungus fruits abundantly on infected trees for several years after felling. If the wood

is not to be utilized or the trees burned the trees should be girdled and permitted to remain standing. This allows less fruiting of the fungus than felling the trees and leaving them on the ground.

STRUMELLA CANKER OF OAKS

Strumella canker of oaks is caused by the fungous parasite *Strumella coryneoidea*, which attacks primarily oaks and occasionally other hardwoods. The red and black oaks are more susceptible than the white oaks. The disease is known to occur from New England to the southern Appalachians, being most abundant and destructive in Pennsylvania, New Jersey, and Connecticut.

On the young smooth-barked oaks the disease is characterized by sunken lesions from an inch to a foot or more in length, usually irregular in outline, with the lips of healing folds conspicuous around the edges of the lesions (fig. 12). The bark often remains on the lesion. Almost invariably it is possible to find near the center of the lesion a branch stub through which the fungus gained entrance. On trees more than 6 or 7 inches in diameter breast high the cankers are usually conspicuous "cat faces", somewhat sunken, with flaring margins. A distinct overgrowth usually occurs on the side of the trunk opposite the canker, resulting in a crook. The wood exposed by the lesions is often attacked by borers. Large cankered trees such as that shown in figure 13 commonly break over. The fruiting bodies of this fungus, which are small, raised, brown, powdery pustules about one eighth inch high, are rarely found on the bark of active cankers, but occur on dead branches or sprouts connected with the cankers. After the death of an infected tree they commonly develop abundantly over the trunk and branches.

Trees with Strumella canker, like trees with Nectria canker, should not be selected as crop trees, and should be eliminated if sanitation is practiced. The fruiting habits of this fungus are opposite to those of the Nectria. The Strumella fungus fruits sparsely, if at all, after the tree is felled, but fruits abundantly if the tree is girdled and allowed to remain standing. Infected trees, both living and dead, should therefore be felled, and should preferably be removed for utilization or burned. Particular care should be taken not to overlook infected sprouts and trees of small diameter; *Strumella* on such material fruits abundantly, making it an important source of infection.

HYPOXYLON CANKER OF POPLAR

Hypoxylon canker (or black canker) of poplar is caused by the fungus *Hypoxylon pruinatum*, which attacks principally aspen and to a lesser extent largetooth aspen and occurs occasionally on balsam poplar. It is very common throughout northern New England, New York, and the Lake States, becoming scarce farther south. The disease is responsible for heavy losses in aspen, causing the trees to break over at the cankers. It is one of the limiting factors in aspen production in parts of New England and of the Lake States.

FIGURE 12.—Canker caused by *Strumella coryneoidea* on young scarlet oak.

II. pruinatum enters through wounds in the bark and dead branch stubs. It rapidly kills the bark and causes the outer bark to flake off, exposing the dead and blackened cortical tissues. These cortical tissues are much checked, with the longitudinal fissures particularly evident. The clustered pustules of the fungus usually occur in abundance over the surface of the killed bark. The canker is very conspicuous. Breaking of the stem at the canker is common even when no decay has entered. The weakness of poplar wood makes the trees very susceptible to breaking.

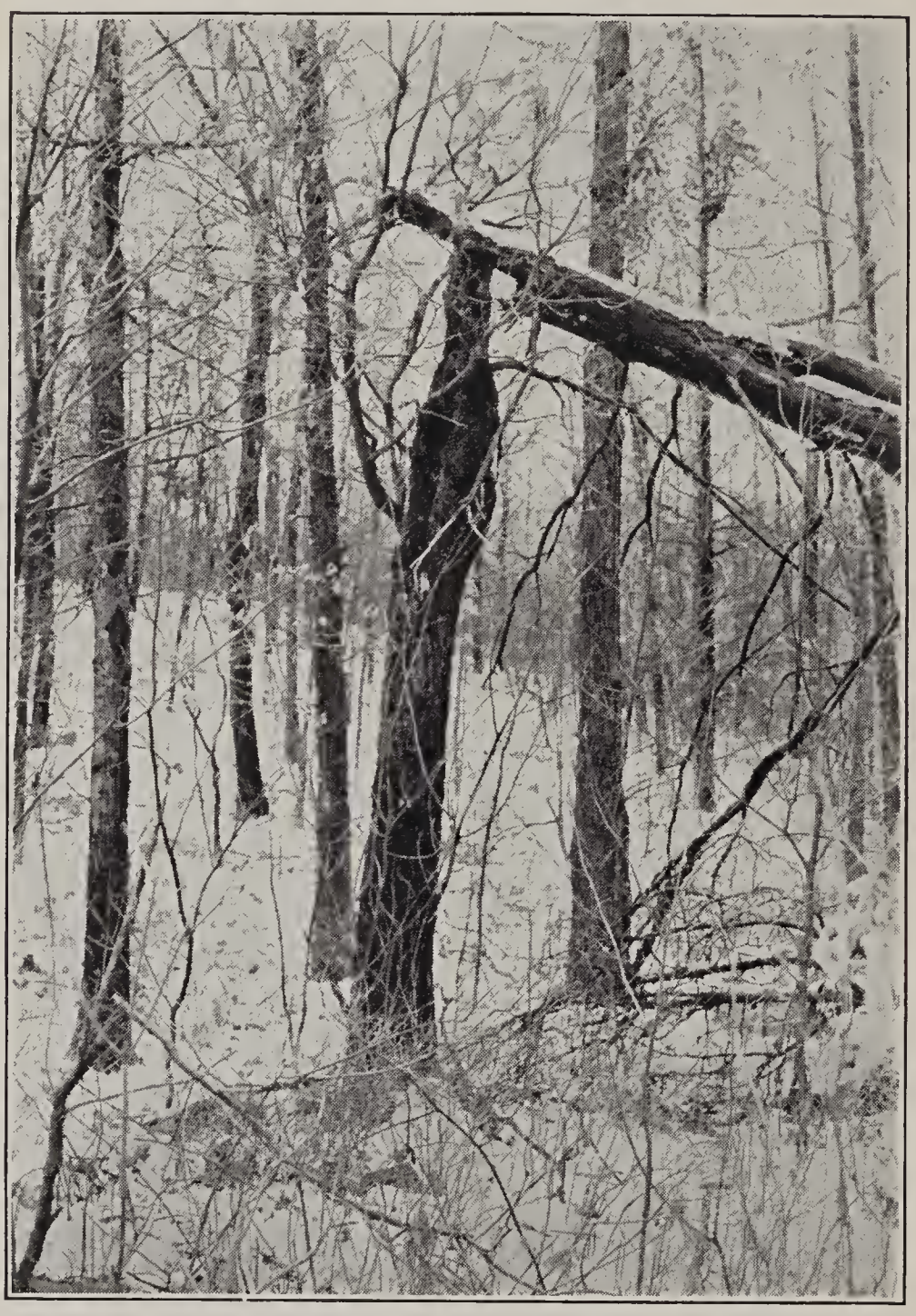

FIGURE 13.—Oak broken over as result of weakening by Strumella canker

Poplar in the Northeast is subject to several other canker diseases. One of these caused by *Cytospora chrysosperma* is severe principally on young poplars 8 to 15 years old that are somewhat suppressed or that for some other reason are not growing vigorously.

Where poplar or aspen is being grown for commercial purposes, all precautions should be taken to keep the stands as free from cankers as possible. In order to protect sound trees from infection, wherever possible diseased trees should be removed from the woods or burned. Poplars in a vigorous growing condition are less suscep-

tible to canker than those that are suppressed and slow growing; therefore any measure that improves the growth of the trees tends to reduce the quantity of canker in a stand.

BLISTER RUST OF WHITE PINE

Blister rust is the most destructive disease of white pines in this country. It was introduced into the United States early in the present century. In the East it is now known to occur throughout New England, as far south as western Maryland and northern Virginia, and throughout the Lake States. It affects all the eight species of five-needled pines native to this country.

The disease is caused by the parasitic fungus *Cronartium ribicola*. It cannot spread from pine to pine. From diseased pines it spreads to currant and gooseberry plants (species of Ribes), and thence to pines. The fungus enters the pine bark through the needles. In some cases it invades the pine trunk directly through the needles; more commonly, it grows downward into the trunk through twigs and branches. It then girdles the tree, causing its death. The areas of diseased bark are called cankers. The characteristic spore stage on the pine, the blister or aecial stage, first appears about 3 years after infection takes place. Thereafter the aecia develop every spring, from April to June. The aecia appear as raised yellowish blisters on the surface of the diseased bark (fig. 14A). The spores liberated when the aecia are ruptured are blown by the wind to great distances, and infect the leaves of Ribes plants. The fungus develops on the Ribes leaves in two stages, known respectively as the uredinial and telial stages: First, during the summer, it produces orange pustules containing spores that infect other Ribes plants; later in the summer, and in the fall, it produces small hairlike columns on which are developed the spores that infect the pines. (See inserts, fig. 14.) A tree infected with blister rust is invariably killed, unless the infected part dies before the canker reaches a vital point on the tree. The killing process may be slow or rapid, depending on the number of infections and the time required for them to reach and girdle a vital portion of the tree.

Because the spread of this disease is dependent upon the presence of an alternate host, the Ribes, and because of the relatively short distance over which the disease spreads from Ribes to pines, control can be effected by eradicating all Ribes within 900 feet of the trees.

In stands of pines already infected with blister rust, losses can be reduced through judicious cleaning and pruning; but such treatment is of no value until further infection of the trees has been prevented by eradicating the Ribes. Usually most of the infections occurring on young pines are located on branches in the lower half of the crown, and the systematic pruning off of this portion of the crown removes many cankers that would otherwise reach the trunk and kill the tree.

Except for the removal of obviously worthless trees, thinning operations in infected stands should be postponed until at least 3 to 5 years after thorough eradication of Ribes. This period of time is often required for the existing rust infections in the trees to become readily visible. The workmen who do the thinning must have thorough training in recognizing cankers and in distinguishing

FIGURE 14.—White pine blister rust: A, Aecial stage on white pine; upper insert, uredinial stage (orange-colored pustules) on Ribes; lower insert, telial stage on Ribes. (The photographs showing the uredinial and telial stages are greatly enlarged.)

between those that have reached a vital point on the tree and those that can successfully be removed by pruning. Infected trees that cannot be freed of dangerous cankers by pruning should be removed if this will leave an adequate stand of codominant, intermediate, or lightly suppressed trees of good form and without visible cankers. Owing to the greater abundance of their foliage, dominant trees usually become more heavily infected than smaller trees in the same stand. Therefore, for effective thinning of an infected stand it is necessary that the trees to be favored be selected primarily on the basis of their freedom from killing infections rather than on that of dominance. In old stands infection is most prevalent in the tops of the trees; in such stands it is best to cut diseased trees promptly in order to salvage as much of the timber as possible.

PLANTATION DISEASES

Where plantations are established for the purpose of growing timber they should be kept as free from disease as possible. Since planting trees is usually an expensive method of establishing a stand, compared with natural regeneration, all possible precautions should be taken to protect planted stock from dangerous enemies. Plantations, because they are even aged and commonly are of a single species, are particularly susceptible to sweeping epidemics. The sweetfern rust and blister rust are capable of ruining entire pine plantations.

SWEETFERN RUST OF HARD PINES

Sweetfern rust affects a large number of two- and three-needled pines, including ponderosa, lodgepole, shortleaf, loblolly, pitch, and Scotch pine. Ponderosa pine, when planted in the East, is particularly susceptible to it. The causal fungus, *Cronartium comptoniae*, has largely the same range as its favorite hosts, the pitch pine and sweetfern, being common throughout the Northeast and the Lake States. It requires an alternate host to complete its development, and in other aspects of life history is essentially similar to white pine blister rust. Its alternate hosts are the sweetfern and the sweetgale (*Myrica gale*). Cankers resembling those of white pine blister rust (fig. 14) are formed near the base of the tree. The cankers are usually swollen and covered with pitch which exudes from them. The yellow blisters (aecia) are formed in the spring.

C. comptoniae is particularly damaging in plantations because it girdles small trees or causes them to be severely stunted and deformed. An infected tree is not likely to be killed by the disease after it attains a diameter of 3 inches or more at the base, although frequently it is deformed.

Within the active range of *C. comptoniae*, plantations of susceptible species should not be established where sweetfern or sweetgale is common, nor should such species be grown in nurseries about which these hosts are common. If susceptible species have been planted where sweetfern is common and some of the trees become diseased, these should be weeded out immediately to keep the fungus from spreading in abundance to the sweetfern and thence to unaffected trees. The same measures should be taken in nurseries. It is much

more expensive and difficult to eradicate sweetfern than to eradicate Ribes, thus sweetfern eradication, even over a closely restricted area, is hardly feasible economically. Where infections occur in nurseries the seedling beds should be repeatedly sprayed with Bordeaux mixture or lime-sulphur.

NEEDLE RUSTS OF CONIFERS

Rust diseases that produce yellowish blisters on the needles of conifers (fig. 15) are numerous. Practically all conifers are susceptible to one or more of them. Although these diseases occur commonly, they cause serious damage only in occasional instances. This occasional damage, which almost invariably occurs in a plantation, consists in reducing the quantity of active leaf tissue through killing needles and parts of needles.

The many fungi that cause these needle rusts require alternate hosts to complete their development. Each of them has a different alternate host. The most important of these fungi on the eastern pines belong to the genus Coleosporium. Among the commonest alternate hosts of the Coleosporiums are goldenrod, aster, and ironweed.

When needle rusts are severe in plantations it sometimes pays to stop them. Eradication of the alternate hosts for a distance of 300 or 400 feet around a plantation should reduce infection to a negligible quantity. It may be necessary to mow down the plant (e.g., goldenrod) two or three times during the summer.

Since in order to control one of these diseases it is necessary to know what plant is the alternate host, correct diagnosis of the specific fungus causing the disease is absolutely necessary. This requires the services of a trained pathologist.

OAK RUST OF HARD PINES

Oak rust of hard pines produces globose galls on a number of eastern species of two- and three-needled pines. It occurs from Vermont to Florida, being most prevalent in the Middle Atlantic and Southern States. These galls are particularly common on Virginia pine and shortleaf pine. The disease is caused by the rust fungus *Cronartium cerebrum*, the alternate hosts of which are species of Quercus, particularly the black oaks and post oak. Another type of this disease, producing spindle-shaped cankers on two- and three-needled pines, particularly loblolly, and having its alternate stage on the same group of oaks, is referred to sometimes as being caused by *C. cerebrum* and sometimes as being caused by *C. fusiforme*. Whether or not these fungi are the same is an unsettled question.

This disease is found in pines of all ages, being particularly severe on young trees. It produces distortions and swellings on the trunk and branches (fig. 16), sometimes killing the part above the lesions. Affected trees in plantations should be removed to reduce the chance of further infection. As it is impractical to attempt eradication of oaks, susceptible pines should not be planted in localities where the disease is prevalent.

ARMILLARIA MELLEA ROOT ROT

Armillaria mellea is a fungus that causes a root rot in all kinds of woody plants throughout the United States. In forest stands beyond

the sapling stage it commonly attacks chiefly trees weakened from other causes, often completing the work of killing them. It is capable of killing young conifers of any degree of vigor. After killing a tree the fungus continues to develop in the roots and butt

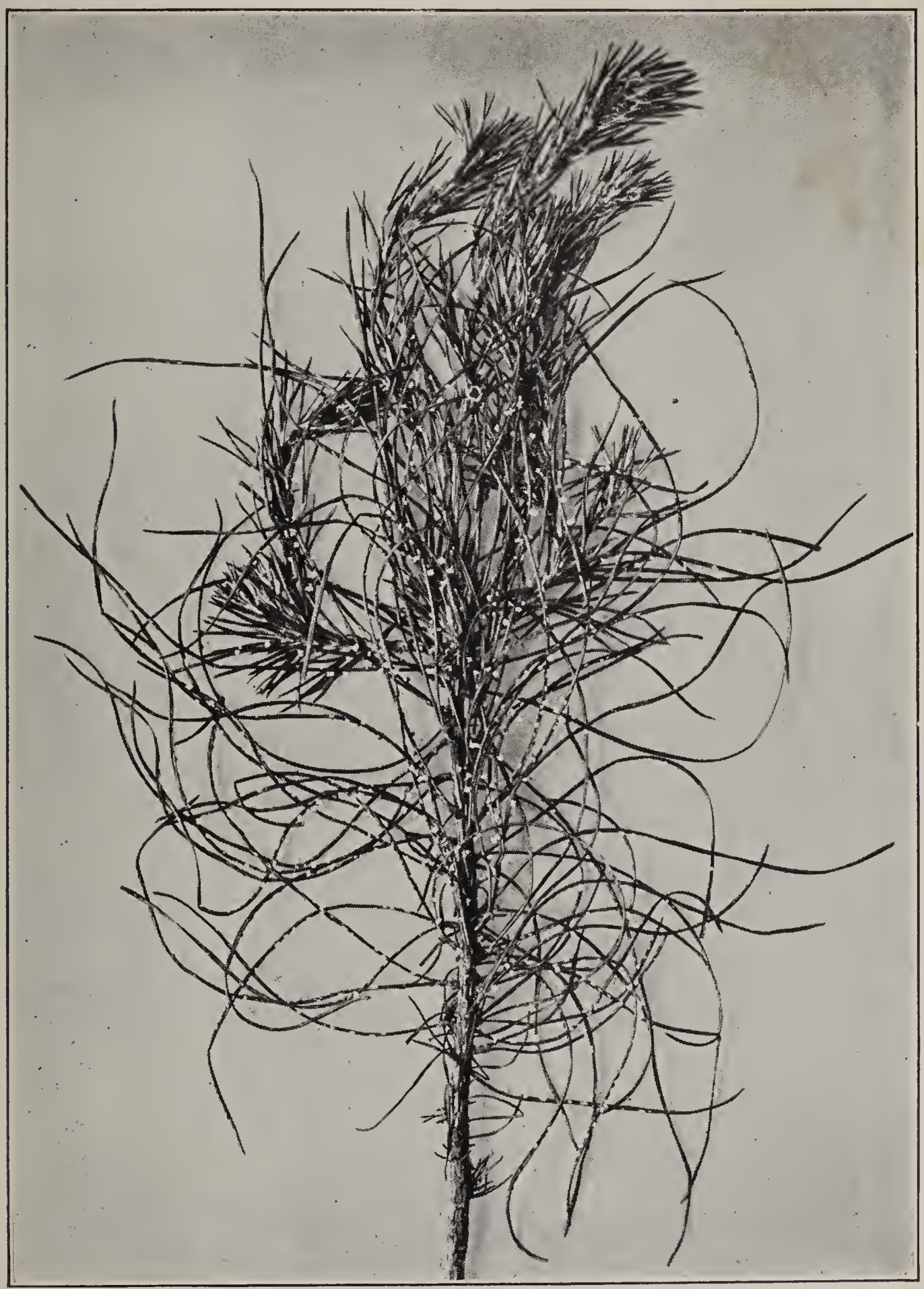

FIGURE 15.—Needle rust on Virginia pine, caused by *Coleosporium inconspicuum*.

or in the stump and spreads through the surrounding soil to a distance of several feet. Young conifers attacked by *A. mellea* spreading from an old stump are usually killed outright. The disease has been observed to be doing severe damage to pine plantations in New York on areas where many old stumps are present.

Trees killed by this disease often are found to radiate from the focus of a stump. The root collars of the young diseased conifers are sometimes swollen, and exhibit a copious exudation of pitch. The fungus produces characteristic black, shoe-string-like strands by which it spreads through the soil, and these strands can often be found about the roots and root collar of a diseased tree. The fruits of this fungus are fleshy mushrooms, which occur in clusters about the base of a diseased tree. These are not to be relied upon for

FIGURE 16.—Gall rust of two- and three-needled pines caused by *Cronartium cerebrum*.

diagnosis, as in many instances they are not produced even on trees killed by the fungus.

Nothing can be done to protect trees planted in soil infested with *A. mellea*. In general, coniferous trees should not be set out on areas where stumps are common and the disease is prevalent on nearby natural reproduction.

THREATENING INTRODUCED DISEASES

Information as to the occurrence of certain forest tree diseases outside their present known range is particularly desired at the present time by the United States Department of Agriculture. These diseases, with the possible exception of the pine twig canker, have been

introduced into this country from foreign lands. Efforts are being made to eradicate two of them, the Dutch elm disease and the larch canker. The following descriptions are given with the request that readers observing any of these diseases outside the ranges mentioned report their observations to the Division of Forest Pathology, United States Department of Agriculture, Washington, D.C., or, in the case of the Dutch elm disease, to the Ohio Agricultural Experiment Station.

LARCH CANKER

Larch canker is a highly destructive European disease of larch that has recently been found in Massachusetts. The canker appears as a depression in the trunk or branch. The trunk usually shows abnormal thickness around the edges of a canker and on the side opposite a canker. Cracked, peeling bark, and the presence of large quantities of resin about the cankers, are other symptoms of this disease. The disease is caused by the fungus *Dasyscypha willkommii*. The fruiting bodies are small and cup shaped. They are about one tenth inch in diameter, are white outside and yellow to orange inside, and are attached to the bark by a short stalk.

PINE TWIG CANKER

Pine twig canker has been found very recently to occur widely through the East on various pines, especially pitch, Scotch, loblolly, and slash pine. The canker occurs chiefly on the twigs and branches. Usually somewhat of a swelling is observed about the cankered area. Small, black, irregularly cup-shaped fruiting bodies are commonly found in association with the cankers. Twigs and branches affected by this disease usually die. The disease can be spotted at some distance by the killed twigs, which retain their dead needles for some time. The disease is caused by a fungus that at the present time is referred to as *Atropellis pinicola*, although its exact status is still in doubt.

WOODGATE RUST

Woodgate rust is a disease of Scotch pine found abundantly in the vicinity of Woodgate, N.Y. (Adirondack region), at a few other points in New York, and in Ontario and Quebec, Canada. It is caused by a rust fungus that spreads from pine to pine, requiring no alternate host. The rust produces globose galls similar to those of *Cronartium cerebrum* (fig. 16) on the branches and the trunk, which result in deformation and killing of the affected parts.

DUTCH ELM DISEASE

The Dutch elm disease, which has destroyed many elm trees in Europe, was found in this country in Cleveland and Cincinnati, Ohio, in 1930, and recently in the general vicinity of Maplewood and South Orange, N.J. The American elm is highly susceptible to this disease. The first symptom is the wilting, or yellowing, or browning of leaves. This is followed by the dying of twigs and branches and ultimately by the death of the entire tree. If the dead branches are cut in two, brown streaks are found running through the young sapwood. The disease is caused by a fungus known as *Graphium ulmi*. Positive identification of this disease as distinguished from certain

related diseases necessitates growing the causal fungus in pure culture. If any elms are found exhibiting the symptoms mentioned, specimens should immediately be sent to the Dutch Elm Disease Laboratory, State Agricultural Experiment Station, Wooster, Ohio.

BEECH BARK DISEASE

The beech bark disease has destroyed more than one third of the beech trees of Nova Scotia and many of the beeches of southern New Brunswick. It has recently been found in Maine. This disease develops following attack by the European beech-scale insect, which has now been found as far south as Massachusetts. A species of Nectria similar to that mentioned earlier in this paper as causing a canker of hardwoods is involved. The fungus apparently enters through the small punctures left in the bark by the scale insect. The bark is killed, without the formation of definite cankers, and the trees die 2 or 3 years after they are attacked. The scale insect appears as a white cottony fluff on the bark. Later the fungus appears on the bark as small red pustules.

WILLOW SCAB

The willow scab disease is prevalent in New England and west to central New York. It occurs on various species of willow. In the spring the leaves of infected trees become brown and the young twigs become blackened at the tips. Leaves unaffected in the spring may later develop brown spots, especially along the midrib. The disease sometimes spreads through the bark into the twigs and kills them. It can be caused by either of two fungi, *Fusicladium saliciperdum* and *Physalospora miyabeana*.

INDEX OF HOST TREES

INDEX OF DISEASES AND DISEASE-CAUSING AGENCIES

(Boldface indicates photographs)